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Publication date:
2013

Document Version
Publisher's PDF, also known as Version of record

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Citation (APA):
Mweu, M. M., Fournie, G., Hisham Beshara Halasa, T., Toft, N., & Nielsen, S. S. (2013). *Temporal characterisation of the network of Danish cattle movements and its implication for disease control: 2000 - 2009*. Poster session presented at SVEPM Annual Meeting 2013, Madrid, Spain.

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Temporal characterisation of the network of Danish cattle movements and its implication for disease control: 2000 - 2009



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Background

- Social network analysis provides a valuable framework for understanding the dynamics of diseases on networks as well as a means for defining effective control measures.
- An understanding of the underlying contact pattern for a susceptible population is advisable before embarking on strategies for disease control.
- Availability of longitudinal data permits creation of successive static networks making it possible to assess the temporal stability of the overall network structure.

Objective

- To characterise the network of Danish cattle movements over a 10-yr period from 2000 - 2009 with a view to understanding: (1) cohesiveness, (2) influential holdings and (3) structural vulnerability of the network.

Methods

- A total of 120 directed monthly networks were created by aggregating individual cattle movements (arcs) between source and destination premises (nodes).
- Network cohesiveness was evaluated based on distributions of density, clustering coefficient and average path length.
- Influential holdings were identified based on their centrality scores – betweenness, closeness and degree – with premise types having the highest scores deemed the most central.
- Structural vulnerability was assessed by removal of the most central premises in the networks followed by recalculation of the sizes of giant strong components.
- The networks were assessed for the presence of scale-free and small-world properties.

Results & Discussion

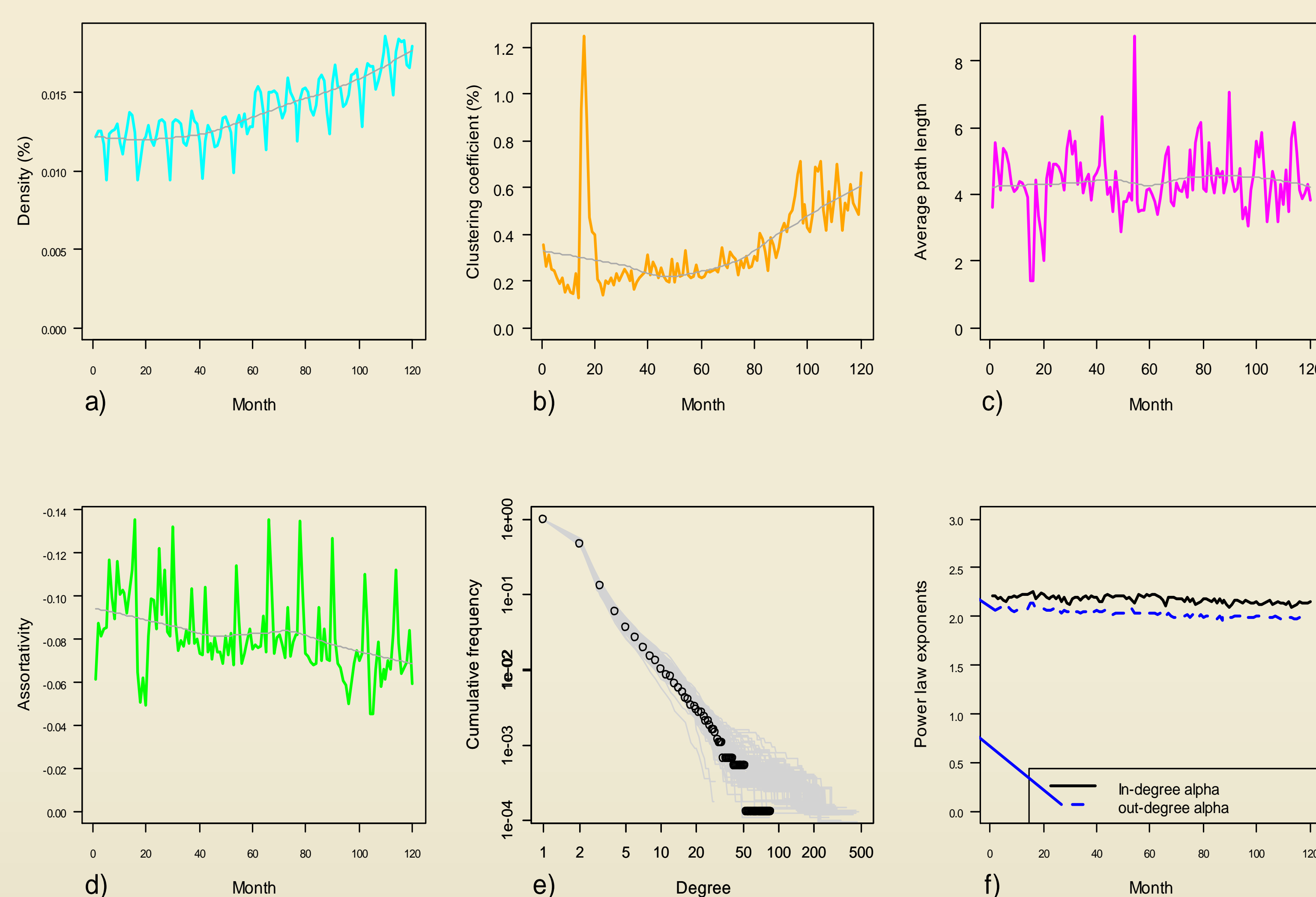


Fig. 1 Plots of the distributions of (a) density, (b) clustering coefficient, (c) average path length, (d) assortativity coefficient (with smoothing averages indicated by continuous dark grey lines), (e) in-degree distributions for Jan. 2000 (black) (underlain by the in-degree distributions for the other months [light grey]) and (f) power law exponents in the monthly networks of Danish cattle movements during 2000 – 2009.

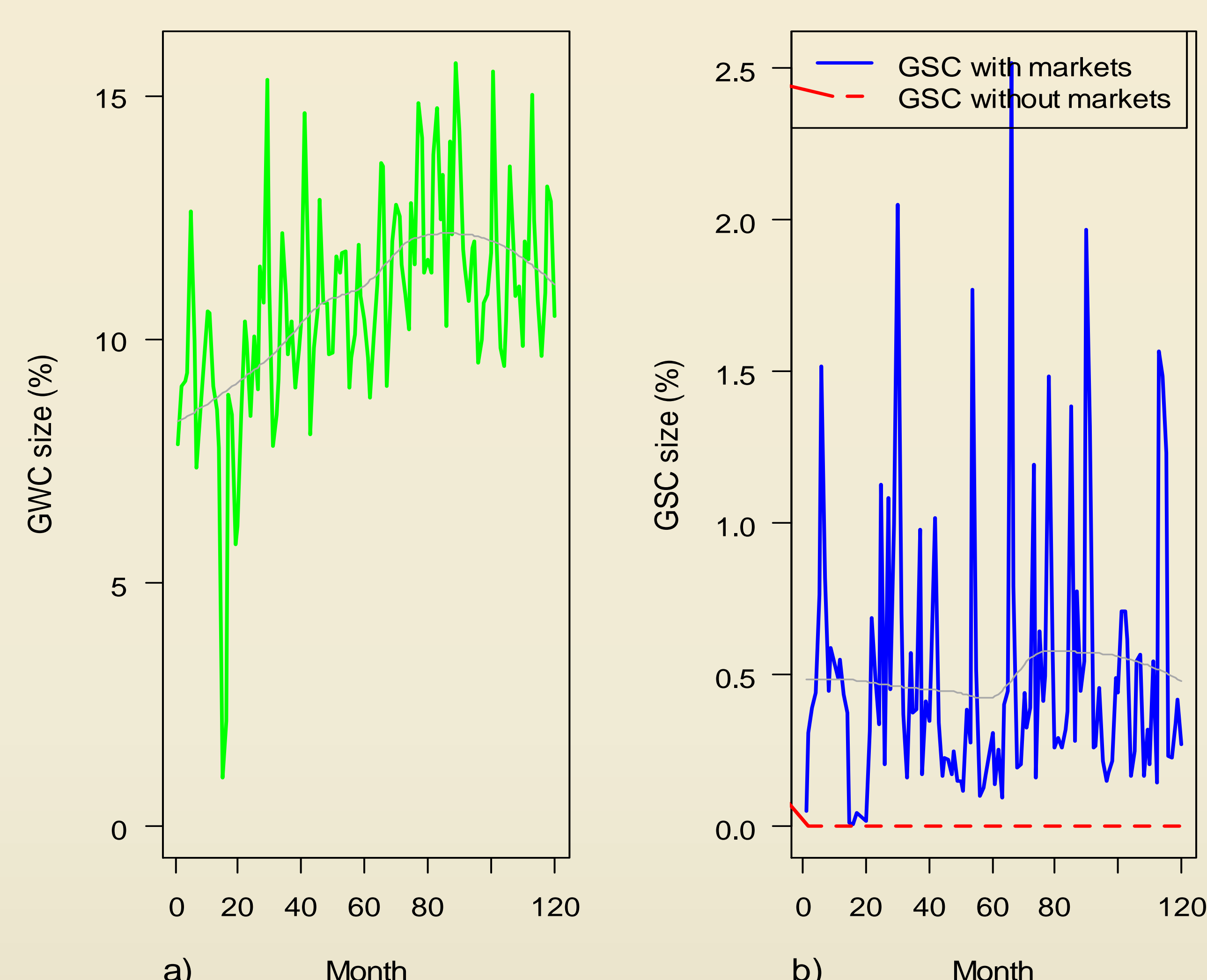


Fig. 2 Plots of the distributions of (a) giant weak component (GWC) and (b) giant strong component (GSC) (before and after removal of markets) in the monthly networks of Danish cattle movements during 2000 – 2009. Smoothing averages are indicated by continuous dark grey lines.

- The network was sparsely connected implying that an epidemic is likely to spread minimally locally, but rapidly through the network.
- In- and out-degree distributions were power law distributed suggesting the presence of hubs, and thus a potential for rapid spread of epidemics on the network.
- Markets were the most influential holdings having the highest centrality scores.
- Removal of markets from the networks led to disappearance of GSCs underscoring the importance of focussing control efforts on highly connected holdings.
- Small-world properties were observed in March – April 2001 and 24 other months between Oct. 2006 and Dec. 2009. Their appearance in March to April 2001, which coincided with the occurrence of the 2001 UK FMD epidemic, suggested the existence of local clusters with possibilities of long-distance connections.

Conclusions

- The network was characterised by a co-existence of both scale-free and small-world properties suggesting heterogeneity in contacts amongst herds.
- Network was sparsely connected with markets as the influential holdings.
- Its vulnerability to removal of markets suggests that targeting highly connected holdings during epidemics should be the focus of control efforts.